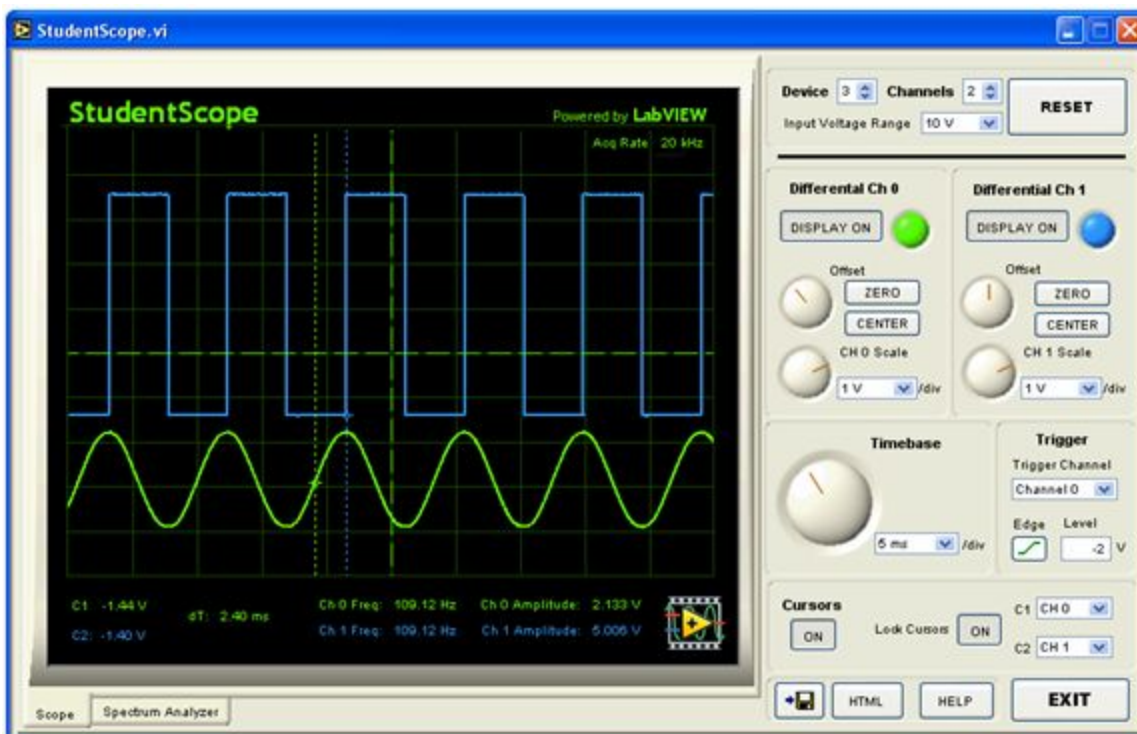


1. [Student Scope Using NI USB Data Acquisition](#)
2. [IR Remote Control Lab](#)
3. [Diode IV Sweep Lab](#)
4. [LED Thermometer Lab](#)
5. [Sound Recorder Lab](#)
6. [Microphone FFT Lab](#)

## Student Scope Using NI USB Data Acquisition

### LabVIEW Student Scope Using the NI USB Data Acquisition

The StudentScope is a software oscilloscope specifically designed to work with the [National Instruments USB-6009 data acquisition device](#). To simulate the functionality of a scope, the StudentScope acquires analog input data across two channels and then searches for a user-specified trigger level. This allows periodic waveforms to be lined up and displayed as standing waves. Controls to scale signals, apply vertical offsets, adjust the timebase, and measure phase offsets are all meant to function similarly to a benchtop oscilloscope. Several expanded features are also available, including a option to log data to an Excel-compatible spreadsheet file or to export a screenshot to a printable HTML report.



StudentScope Front Panel

## Download the StudentScope

The StudentScope source code can be downloaded here: [StudentScope Source \(1.0\)](#). The StudentScope source requires: [LabVIEW](#) 8.0 or later, and [NI DAQmx](#) 8.0 or later.

The StudentScope stand-alone executable can be downloaded here: [StudentScope.exe \(1.0\)](#). The StudentScope executable requires: [LabVIEW RunTime Engine 8.0](#), and [NI DAQmx](#) 8.0 or later. You must extract all files from the zip distribution before attempting to use the source or executable versions of this application.

## Getting Started

First, be sure you have the LabVIEW Run-Time Engine version 8.0 and the DAQmx driver version 8.0 or later installed under the default installation options. Both can be downloaded free of charge from ni.com. The installer included with the Student Scope includes the LabVIEW Run-Time Engine, but DAQmx must be downloaded separately. Next, connect your [National Instruments USB-6009](#) to your PC. Windows should detect the device and configure the appropriate driver. If this is the first time that a USB-6009 device is installed on your computer, you might be prompted to install a USB-6xxx Firmware Loader. Please complete the Windows Hardware Wizard prompts to completely install this device.

To run the StudentScope, you will need to determine the device number of your USB-6009, which is how the hardware is identified by the scope software. Find this by opening National Instruments Measurement and Automation Explorer (MAX). In MAX, expand Devices and Interfaces. Then expand NI-DAQmx Devices. If the DAQmx driver is installed properly, and the USB-6009 is connected, you will see an item such as USB-6009: "Dev1" where Dev1 indicates device # 1. Make a note of the device number.

When you run the StudentScope, you will need to select the correct device number. If the wrong device number is selected, you will receive an error

message. To fix this, be sure the USB-6009 is plugged in, select the correct device number, and press the reset button.

## **Hardware Connections**

Connect input signals to differential channels 0 and 1 on the USB-6009. Terminals 2 and 3 on the 6009 correspond to the positive and negative inputs for differential channel 0. Terminals 5 and 6 on the 6009 correspond to the positive and negative inputs for differential channel 1. For more information on terminals and connections, consult the help manual for the device.

## **Controls**

The following controls on the StudentScope front panel are used to control the behavior of the scope. The controls are modeled after a traditional benchtop oscilloscope.

- **Device:** Specifies the Device Number of the 6009, which uniquely identifies the hardware. This number can be found in Measurement and Automation Explorer (MAX). If you adjust this input, you will have to press reset for the changes to take effect.
- **Channels:** Specifies the number of channels to scan. By acquiring only a single channel of data, twice the sampling rate can be achieved over acquiring two channels of data. If you adjust this input, you will have to press reset for the changes to take effect.
- **Input Voltage Range:** Sets the internal programmable gain amplifier on the 6009. This applies an appropriate analog gain to the signal prior to digitization. For best results, choose the smallest range setting that completely encapsulates the expected signal. If you adjust this input, you will have to press reset for the changes to take effect.
- **Reset:** If Device, Channels, or Input Voltage Range values are changed, the StudentScope needs to be reset for the changes to take effect.

- Display On: Toggles the visibility of each channel's trace. Note: This does not change whether or not the data is actually being acquired by the USB-6009; it merely allows the user to turn on or off the display of that data.
- Offset: Adjusts the vertical position of the trace on the display by adding or subtracting a voltage offset.
- Zero: Removes any offsets added with the Offset knob.
- Center: Automatically adjusts the Offset knob so that the waveform is centered vertically on the display.
- Scale: Sets the Volts per division along the vertical axis in order to "zoom" vertically.
- Timebase: Sets the time per division along the horizontal axis in order to "zoom" horizontally. This does not change the rate of acquisition of the hardware.
- Trigger Channel: Specifies which channel will generate the trigger.
- Edge: Toggles between triggering off of a rising or falling edge of the signal.
- Level: Specifies the voltage level at which a trigger will be generated. Note: If the level is never crossed by the periodic signal, the trigger will not work properly and the waveform will not display correctly. Also, the trigger is defined in software, and will only correctly display periodic signals with a period of less than 1/8 second.
- Cursors (On/Off): Toggles display of the cursors on or off.
- Lock Cursors: Toggles whether cursors are free-floating or locked to a channel trace. If cursors are free floating, the voltage level at each cursor will not be displayed.
- C1: If Lock Cursors is toggle on, this selects the channel to which Cursor 1 is locked.
- C2: If Lock Cursors is toggle on, this selects the channel to which Cursor 2 is locked.
- X Axis Scroll: Adjusts the center frequency of the Spectrum Analyzer. Page Up and Page Down can fine tune this control left and right.
- X Axis Zoom: Adjusts the min and max range of the X axis of the Spectrum Analyzer.

## IR Remote Control Lab

# IR Remote Control Using National Instruments Low Cost Data Acquisition

### Introduction

Have you ever wondered how a typical remote control works? When the user presses a button on the remote, an infrared signal is transmitted across the room and detected by a sensor called a photodetector. You will create a remote control of your own in this exercise.

In this lab, you will use a standard universal remote control to transmit an infrared signal several feet. A detection circuit will then be constructed using a specific type of photoreceiver known as a photodiode. Next, a [Low Cost USB DAQ device](#) will be used to digitize the infrared signal. Finally, this digitized signal will be analyzed using LabVIEW software to control the popular iTunes application with the help of ActiveX controls.

### Pre-Lab Assignment

- 1) Why can't humans see the infrared light coming out of a remote control? Look online or in a textbook to find the wavelengths of the visible light spectrum as well as the wavelengths of the infrared light spectrum.
- 2) Write a short summary about how the photodiode works. You should be able to find a variety of sources online; cite them in your response.
- 3) Search Google for "infrared photodiode datasheet" and see what you can find. What specifications are common for photodiodes? Verify that the photodiode detection range is within the infrared spectrum.
- 4) To generate the infrared signal, your remote control contains an infrared LED. Find an infrared LED datasheet online. What specifications do you

see? Verify that the infrared LED emission range is within the infrared spectrum.

5) Become familiar with the National Instruments USB 6008 and 6009 data acquisition devices. These datasheets are available at [www.ni.com](http://www.ni.com).

## Theory

Infrared signals are very similar to visible light, except they occupy a section of the electromagnetic spectrum that makes them invisible to the human eye. In scientific terms, the infrared spectrum contains wavelengths ranging from approximately 1.0 mm to 0.7  $\mu\text{m}$ . It is convenient to use infrared signals for remote control transmission, because their reception is not strongly affected by the amount of ambient light present at the photodetector.

One common method of converting an infrared remote control signal (0.7 – 0.9  $\mu\text{m}$  wavelength) into an electrical signal is using an infrared photodiode. In addition, another method is using a phototransistor. For this laboratory exercise, we will focus on an infrared photodiode transducer similar to the one shown below:



Infrared  
Photodiode

When used in a circuit, the photodiode will be reverse biased and, as with an ordinary diode, no current will flow. However, any incident infrared light will cause electron-hole pairs to form in the photodiode semiconductor, and thus a current will flow. In this way, an infrared signal can be converted to an electrical one.

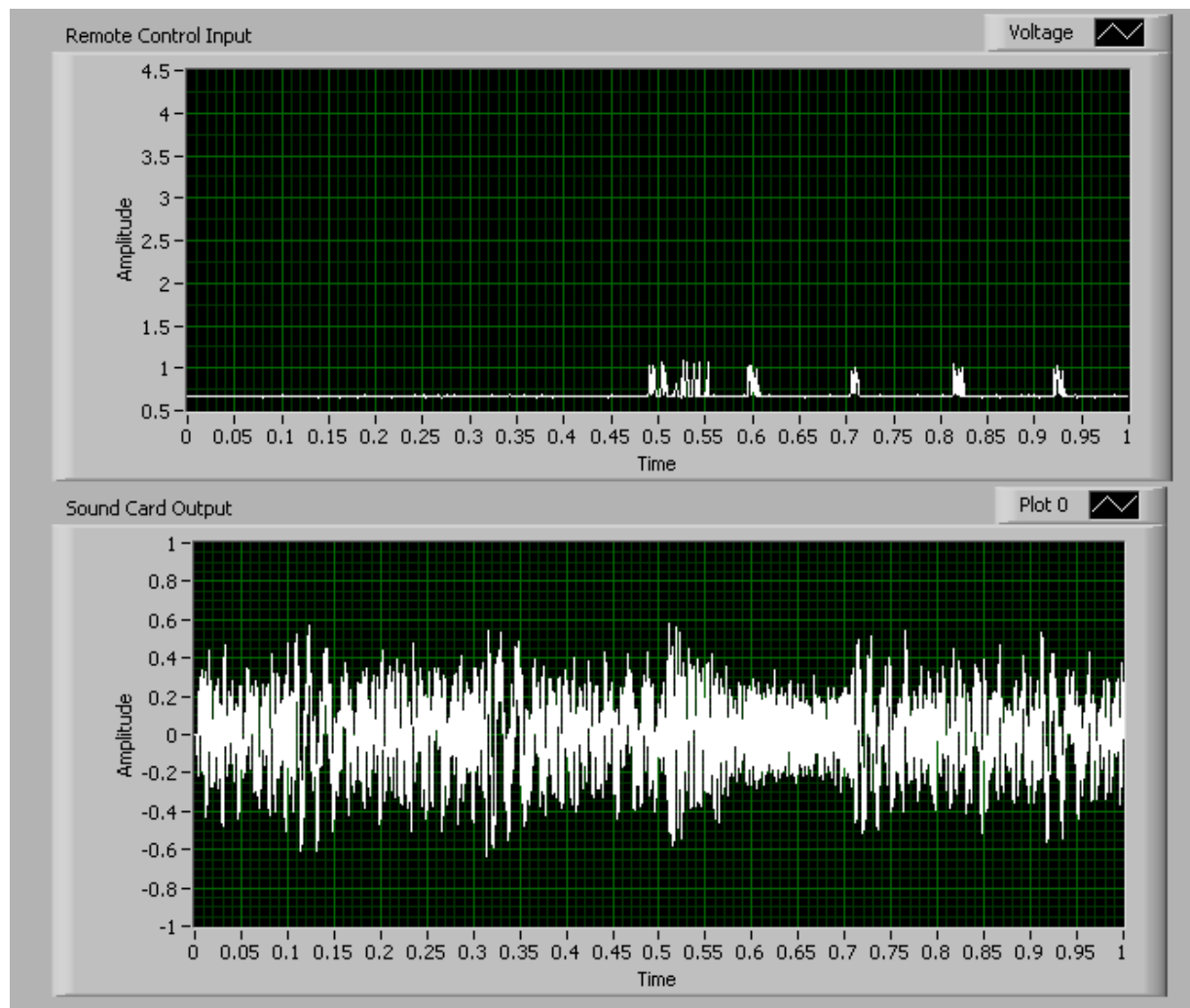
## Hardware and Software Required

1. Infrared photodiode
2. 100 kOhm resistor
3. Remote control (any infrared device should work)
4. [National Instruments Low Cost USB DAQ](#)
5. [LabVIEW 8.20 software \(LabVIEW 8.0 will work as well\)](#)
6. iTunes software

## Laboratory Exercise

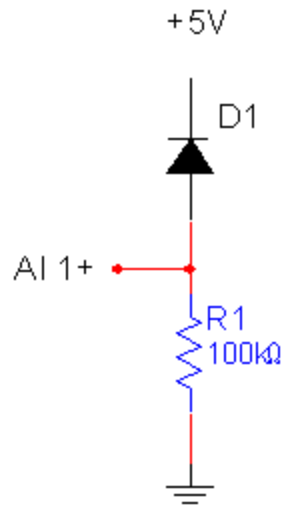
In this exercise, infrared data will be acquired from a photodiode and then digitized using a Low Cost USB DAQ device. Once the infrared signal exceeds a given threshold (meaning that a remote control button is being pressed), LabVIEW will send an ActiveX command to make iTunes play a song. Holding down a remote control button will result in iTunes skipping to the next song in the current playlist. When finished, the LabVIEW front panel will resemble the following:





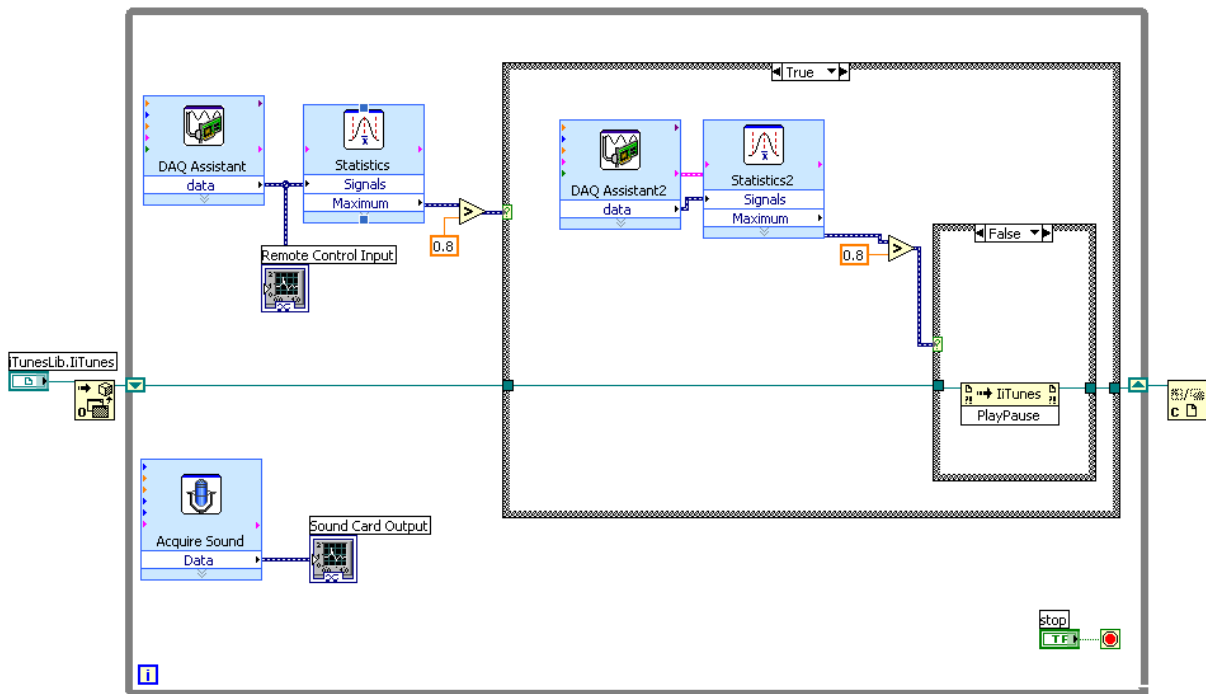
### IR Remote Control Front Panel in LabVIEW

1) Connect the following circuit to the Low Cost USB DAQ as shown. The photodiode can be purchased cheaply at Radio Shack, etc. Note that the +5V power supply can be obtained directly from the National Instruments USB 6008 or 6009 devices.



IR Receiver  
Schematic

2) Using the DAQ Assistant and Acquire Sound Express VIs, create the following LabVIEW block diagram. Note that the false case of the outer case structure simply passes through the ActiveX automation refnum.



IR Remote Control Block Diagram in LabVIEW

- 3) Run the VI and use any infrared remote control to test your application. Pressing a button quickly on the remote control should cause iTunes to play/pause the current song (iTunes will first open if currently closed). Holding down a remote control button should cause iTunes to play the next song in the current playlist.
- 4) Experiment to find out how far away you can use your remote control before the infrared receiver no longer works. Try adjusting the detection threshold to maximize transmission distance without false positives.
- 5) Though infrared photodiodes are not very responsive to visible light, the signal produced could be slightly affected by the ambient light in your room. Try operating the circuit in different lighting conditions and note how the signal level changes.

## **Post-Lab Questions**

- 1) What could be done to increase the working distance of your remote control receiver? Would you implement changes in hardware or software?
- 2) As mentioned earlier, a phototransistor could have been used instead of a photodiode to receive infrared signals. Research some advantages and drawbacks of using each kind of device. Which do you think would work best? Which sensor costs the most?
- 3) Experiment with the ActiveX VIs in LabVIEW and see what other applications you can control. How could you make a PowerPoint slideshow advance when an infrared signal is received by your detection circuit?

## Diode IV Sweep Lab

# Diode IV Sweep Using National Instruments Low Cost Data Acquisition

### Introduction

The diode is a basic circuit element that possesses nonlinear IV characteristics. In contrast to a simple resistor, doubling diode current does not necessarily double the voltage across the diode. In order to visualize this nonlinear relationship, it is common to plot diode current vs. voltage on a 2D graph. This graph can also be used at a later point to perform “load line” calculations on circuits with diodes.

In this exercise, the experimenter will construct a simple circuit to measure the IV characteristic of a diode. The Low Cost USB DAQ will be used as a programmable voltage source as well as an analog measurement device. The experimental data collected can be compared to expected theoretical data to draw conclusions regarding measurement noise, model shortcomings, and data acquisition.

### Pre-Lab Assignment

1. Research the exponential diode model using textbooks, the internet, or any other source. This model is more commonly referred to as the “ideal diode model”. What other diode models can you find?
2. What formula(s) can you find relating diode current and voltage? Note that the exponential, or “ideal diode model” should have an exponential term.
3. Search Google for “Phillips 1N914” and open up the pdf datasheet. Find the graph of diode forward current vs voltage and note your observations. Does the forward IV curve look exponential? How does the reverse IV curve look?
4. Use a simulation package such as Multisim to obtain the IV characteristic of a simulated diode. Do this by sweeping either the

- diode current or voltage, and measuring the other quantity.
5. Become familiar with the National Instruments USB 6008 and 6009 data acquisition devices. These datasheets are available on [www.ni.com](http://www.ni.com).

## Theory

One commonly used method of modeling a diode is the “ideal diode model”. Using this model, diode voltage and current are related according to the following formula:

$$I_D = I_S * \left( e^{\frac{V_D}{V_T}} - 1 \right)$$

Ideal Diode Model

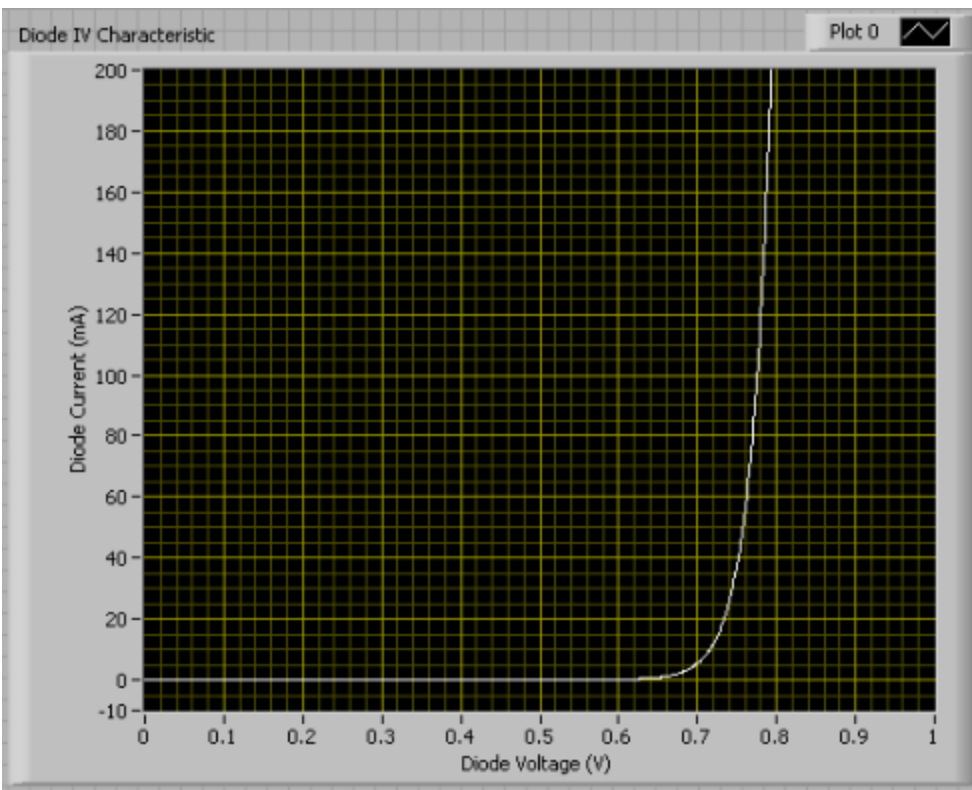
Since  $I_S$  is typically very small (1E-12), this equation is commonly simplified to:

$$I_D = I_S * e^{\frac{V_D}{V_T}}$$

Simplified Diode  
Model Equation

Note that in the formula,  $I_s$  stands for the saturation current which is around  $1\text{E-}12\text{ A}$ , and  $V_t$  is a temperature dependent constant equal to  $0.0259\text{ V}$  at  $300\text{ degrees K}$ .  $I_d$  and  $V_d$  represent diode current and voltage respectively.

Therefore, a theoretical diode IV curve can be plotted using LabVIEW:



IV Curve plotted using LabVIEW

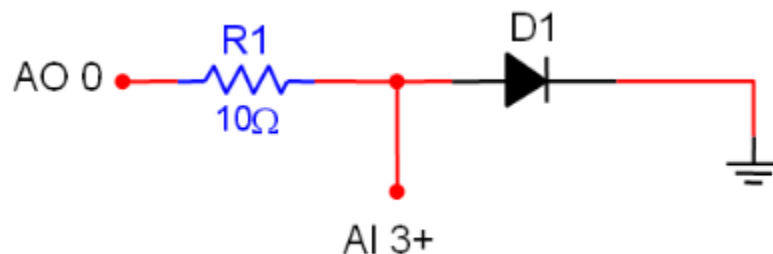
### Hardware and Software Required

1. 10 Ohm resistor
2. Diode
3. National Instruments Low Cost USB DAQ

4. LabVIEW 8.20 software (LabVIEW 7.1 or 8.0 will work as well)

## Labratory Procedure

1) Construct the following circuit and connect to the USB 6008/6009. By outputting a certain voltage at AO 0 and measuring the voltage at AI 3+, the experimenter can obtain a data point containing diode voltage and current. The diode voltage is simply the voltage at node AI 3+, and the diode current is identical to the resistor current (Ohm's Law).

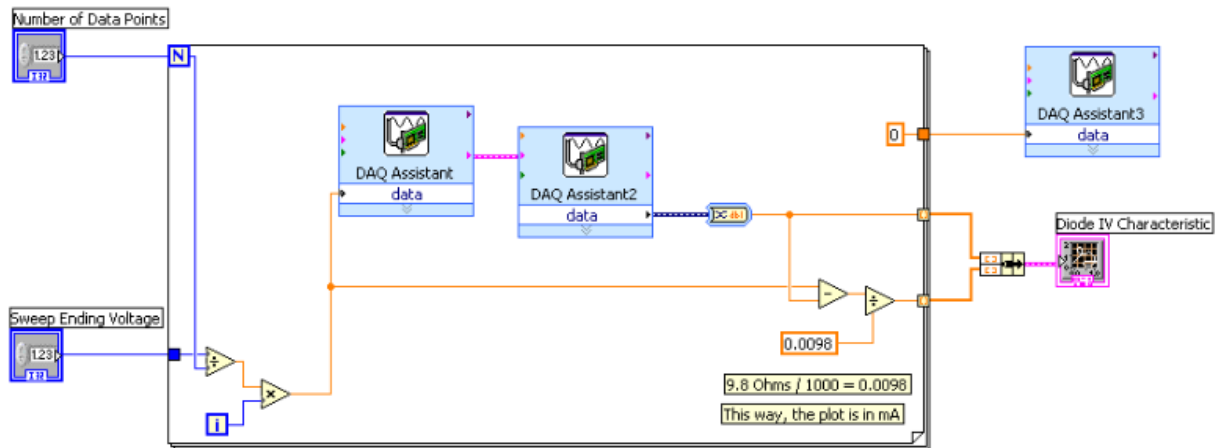


Circuit for Measuring Diode IV Curve

2) Use a DMM to measure the actual resistance used for R1 in the circuit above (take R1 out of the circuit for measurement). This will help to obtain a more accurate current reading.

3) Using the DAQ Assistant Express VI, construct the following LabVIEW block diagram. Note that the user will be able to select the number of IV data points to collect, as well as the ending sweep voltage for AO 0. Select this voltage low enough to ensure that resistor R1 does not exceed its power specification.





LabVIEW Block Diagram Used to Measure Diode IV Curve

4) Run the VI several times using different values for the number of data points and sweep ending voltage. Record your observations and print out three diode IV curves with different numbers of data points.

## Post-Lab Questions

1. Did the measured diode characteristic curve closely resemble what you expected? How closely did this curve match the datasheet, simulation, and theoretical data you researched earlier?
2. The measured IV curve may have contained some noise. Elaborate on some possible sources of this noise (think about your surroundings). Can you think of a way to eliminate some of the undesired noise from the signal? Would you do this in hardware or software?
3. What real-world situations would require a designer to measure the diode characteristic curve?
4. What quantities could you measure for a bipolar junction transistor (BJT) using the low cost USB acquisition device? Explain how you would make your measurements.

## LED Thermometer Lab

# LED Thermometer Lab Using National Instruments Low Cost Data Acquisition

### Introduction

One common measurement that scientists and engineers like to make is temperature. For example, it may be necessary to record the temperature of a biology experiment, a heat testing chamber for electronics, or a jet engine.

In order to convert temperature information into electrical form, a transducer is needed. A temperature transducer is simply a sensor that will allow the user a mechanism to detect a temperature change (increasing or decreasing voltage, current, resistance, etc).

During this exercise, the experimenters will use the integrated circuit LM34CZ temperature sensor to output a linear, temperature dependent voltage. This voltage will be digitized by a Low Cost USB DAQ so that measurements can be taken on a computer. Finally, a LabVIEW virtual instrument (VI) will be created in order to visualize sampled data and control several LEDs.

### Pre-Lab Assignment

1) Many types of temperature sensors exist, including RTDs, thermocouples, thermistors, and ICs. Use any resources available (textbooks, the web, etc) to research each type of transducer and prepare a short written summary of each.

2) Find and print the datasheet for the LM34CZ temperature sensor using Google. By reading the datasheet, can you determine how we will measure temperature with this IC? Write a formula relating temperature and sensor output voltage (this should be fairly simple).

3) Suppose we were using the LM35 temperature sensor instead. Obtain the datasheet and write a second formula relating temperature and sensor output voltage for the LM35.

4) Become familiar with the National Instruments USB 6008 and 6009 data acquisition devices. These datasheets are available at [www.ni.com](http://www.ni.com).

## Theory

One method to measure temperature involves using an integrated circuit transducer such as the LM34CZ. This IC will generate a voltage that is linearly proportional to the measured temperature. Compared to other measurement methods, ICs provide an extremely linear output with very little error. They are also one of the simplest temperature sensors to connect and use.

Below are several views of the LM34CZ in a TO-92 package:

LM34CZ Sensor



Sensor Pinout



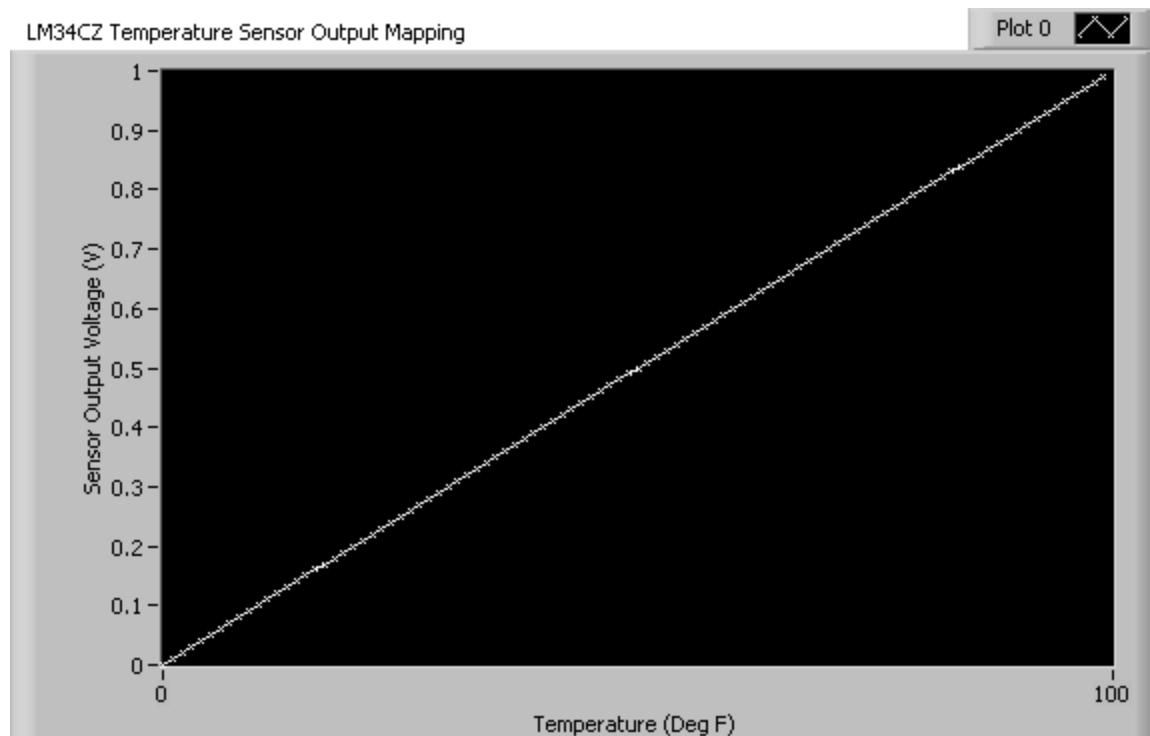
As the experimenter can see, the LM34CZ is a three-terminal device. Two pins are used for power (+V<sub>S</sub> and GND), while the third pin is used to output a temperature dependent voltage.

Since the LM34CZ outputs a voltage that is linearly dependent with temperature, it is easy to compute measured temperature from sensor output voltage or vice versa. In fact, the LM34CZ ideally outputs exactly 10mV / deg F.

$$Temp \text{ (deg } F) = V_{OUT} * 100$$

### Temperature - Voltage Relationship

To visualize this relationship, a graph sensor output voltage vs. temperature can be plotted using LabVIEW:



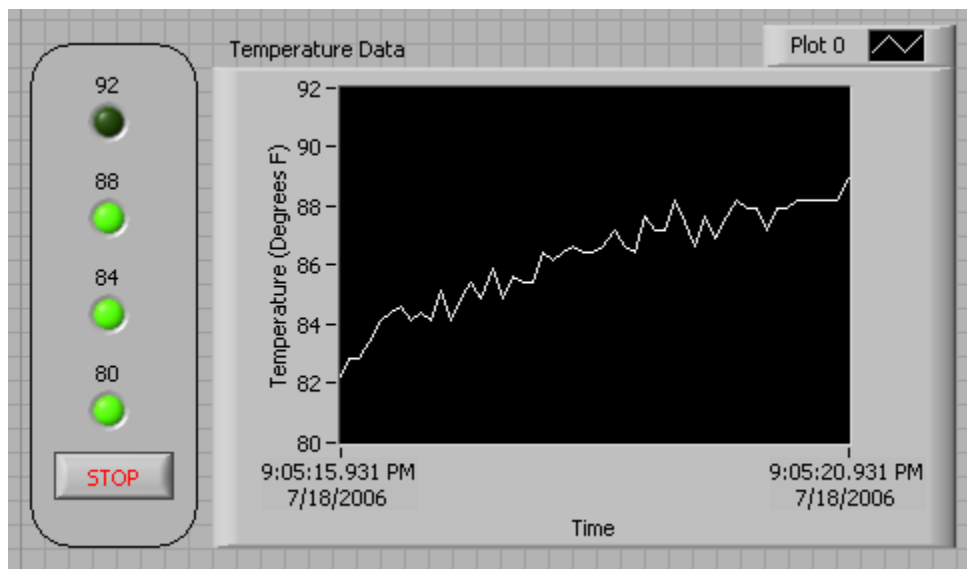
Output Voltage Vs. Temperature Data

## Hardware and Software Required

1. (4) red LEDs
2. (4) 220 Ohm resistors
3. LM34CZ temperature sensor IC
4. National Instruments Low Cost USB DAQ
5. LabVIEW 8.20 software (LabVIEW 7.1 or 8.0 will work as well)

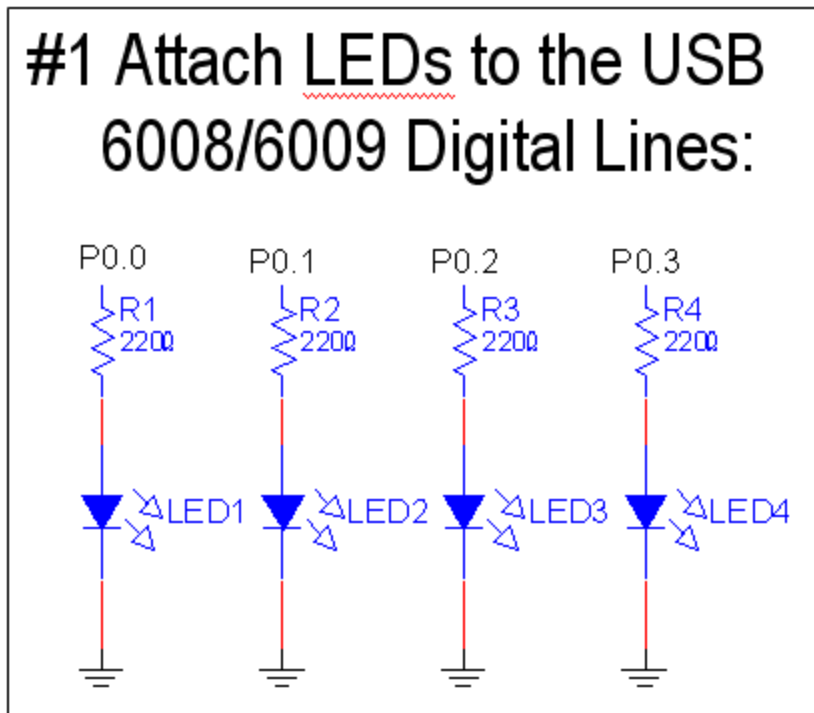
## Laboratory Exercise

During this exercise, the experimenter will construct an LED thermometer that resembles the following:



LED Thermometer Front Panel in LabVIEW

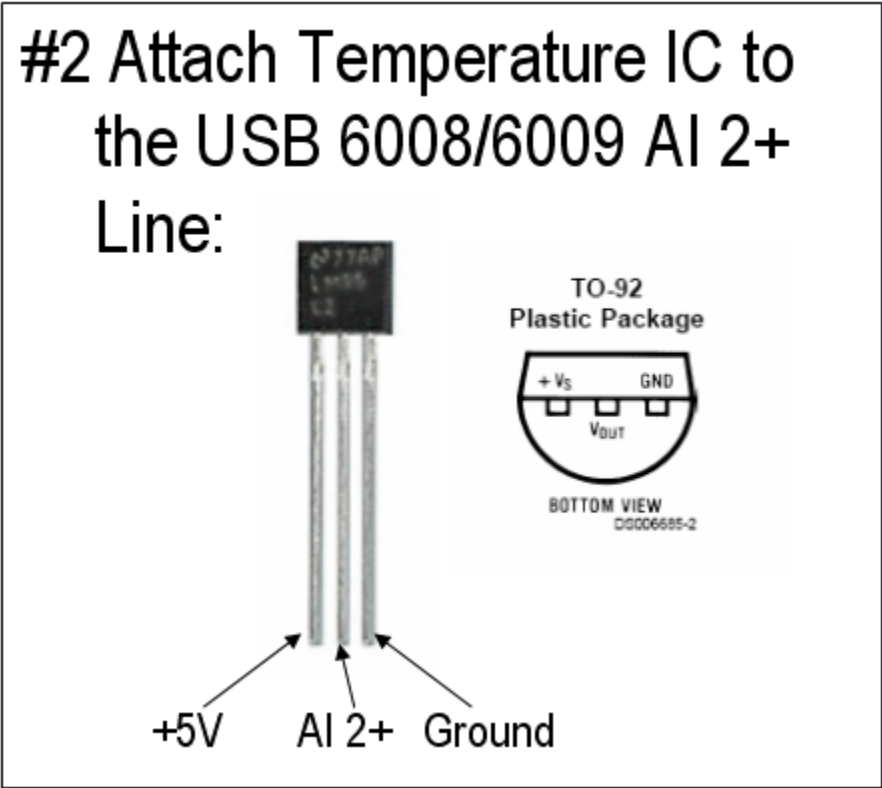
1) In order to create the LED thermometer output, Connect LEDs and resistors to the digital output lines of the Low Cost USB DAQ as shown below. Each LED will be programmed to light up when the temperature exceeds a certain threshold.



LED Connection Schematic

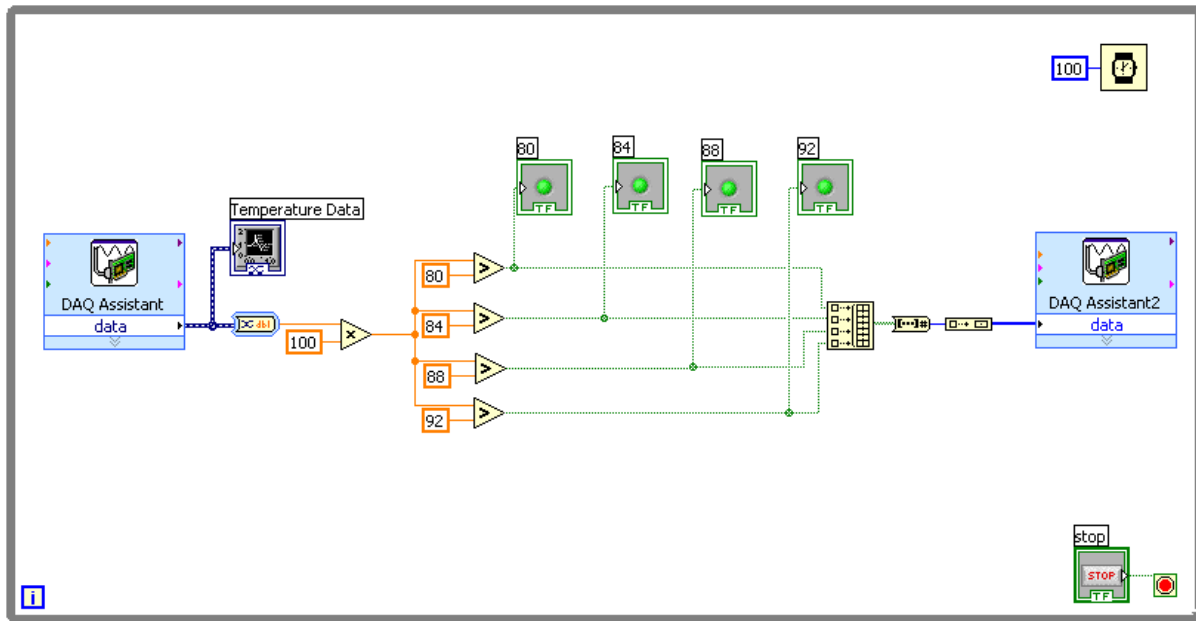
2) To measure the temperature, connect the LM34CZ IC to the Low Cost USB DAQ as shown below. Note that the +5V supply needed by the IC can be obtained directly from the National Instruments USB 6008 or 6009.

## #2 Attach Temperature IC to the USB 6008/6009 AI 2+ Line:



# Temperature Sensor Schematic

3) Using the DAQ Assistant Express VI, create the following LabVIEW block diagram. In this virtual instrument (VI), temperature data is acquired using the Low Cost USB DAQ, scaled, and displayed on a chart. The temperature measurement is also compared with several thresholds. Once the temperature exceeds each threshold, a corresponding physical LED and front panel LED will light up.



LED Thermometer Block Diagram in LabVIEW

4) Run the VI and adjust the threshold levels so that several LEDs light up. Warm up the temperature sensor by squeezing it with your fingers and observe the rise in measured temperature on the front panel chart. You have now succeeded in creating an LED thermometer!

## Post-Lab Questions

1) Did the measured temperature levels match what you expected? If the temperature is warmer or cooler than you expected, elaborate on possible sources of error.

2) Look at the LED Thermometer VI created above, and determine how often temperature measurements are being taken. Why wouldn't you want to take room temperature measurements at a faster rate such as 1 MHz?

3) If you were incorporating the LM34CZ temperature sensor into a shipping product, what would you do to calibrate the sensor? Outline the



process you would go through to make your temperature measurements more accurate.

4) How could you modify the LabVIEW virtual instrument above to output a Centigrade or Farenheit temperature depending on user input? Assume you are using the same LM34CZ temperature sensor.

## Sound Recorder Lab

# Sound Recorder Using National Instruments Low Cost Data Acquisition

### Introduction

Any signal, including a sound wave, can be thought of as the sum of different frequency sine waves (where each frequency wave has a specific amplitude and phase angle). In addition to the frequencies we expect to see in a signal, some undesirable frequencies may also be present.

Filters allow us to select which frequencies we care about, and discard certain frequencies that are undesirable (such as noise). Various types of filters exist including low-pass, high-pass, band-pass, etc. There are also many different ways of constructing each filter type with each filter implementation having its own specific characteristics. More information on filters will be provided in the theory section.

In this exercise, the experimenters will use a microphone element to convert a sound wave into an electrical signal. This signal will then be digitized using a Low Cost USB DAQ device. Finally, a LabVIEW application will be constructed to filter undesired frequencies from the signal and play the clarified signal back.

### Pre-Lab Assignment

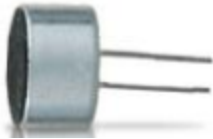
- 1) In your own words, describe what an ideal band-pass filter transfer function would look like. You may research this by searching for “ideal band pass filter” in google, or using a textbook.
- 2) When filtering an audio signal, what frequencies must be preserved? Do some research to determine the frequency range produced by the human voice, and the audible range of the human ear.

- 3) Elaborate on some possible sources of undesirable frequencies in a signal. Where does signal noise come from?
- 4) Become familiar with the National Instruments USB 6008 and 6009 data acquisition devices. These datasheets are available at [www.ni.com](http://www.ni.com).

## Theory

### Electret Microphone Elements

One way to convert sound pressure waves into an electrical signal is using an electret microphone element. A picture of such an element is shown below:



Electret  
Microphon  
e Element

Inside the electret microphone element, a dielectric material is made to hold a permanent charge. When the element vibrates, the internal capacitance changes and an electrical signal is produced. A variety of additional components complete the microphone element circuitry by adding a small amplifier to the output.

### Band Pass Filters

The Fourier Transform tells us that it is possible to think of any signal as being composed of various frequency sine waves (with each frequency having an associated amplitude and phase angle)

Imagine that you have just used a microphone to convert a sound wave into an electrical signal. If the sound wave consisted only of a human voice, then only the frequencies that human vocal chords can produce should be present. Therefore, the overall signal should roughly be composed of frequencies between 80 Hz and 1.2 kHz.

Unfortunately, when playing back your audio signal, you may find that it does not sound very good! Perhaps the lights in your room added some 60 Hz electrical noise to the signal that shouldn't have been there. Maybe the wind was blowing on your microphone, causing the signal acquired to be fuzzy-sounding. There are an enormous number of factors that could affect your sound signal.

Using a filter can help clarify the signal so that it sounds clear once again. Since you know that any frequencies outside of the 80 Hz – 1.2 kHz range are obviously noise, you can attempt to attenuate these frequencies as much as possible. Specifically, a band-pass filter can be used to accomplish this objective.

An ideal band-pass filter will completely attenuate any signals outside of a desired range (known as the passband). In the real world, it is impossible to construct an ideal filter, but with a large enough circuit or complex digital filtering it is possible to obtain a fairly sharp cutoff.

Remember, all filtering is essentially “frequency selection”. By filtering a signal, we are attempting to “choose” which frequency components can pass through and which we want to discard.

## **Hardware and Software Required**

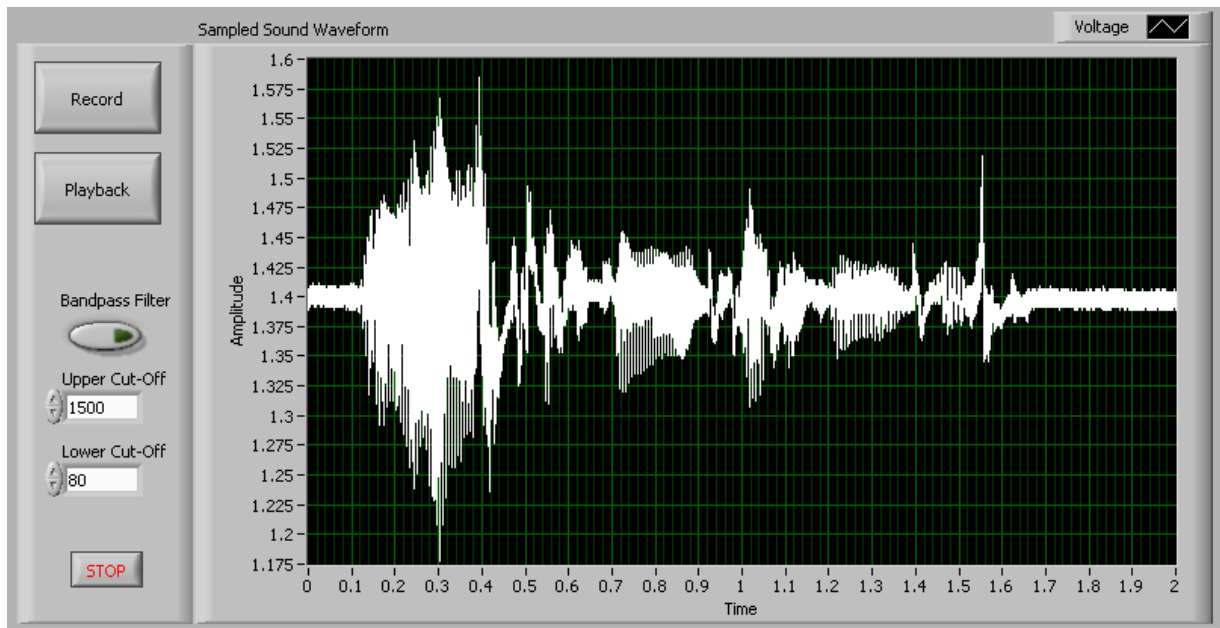
1. 10 Ohm resistor

2. 4.7 uF capacitor
3. Electret microphone element
4. National Instruments Low Cost USB DAQ
5. LabVIEW 8.2 software (LabVIEW 8.0 will work as well)

## Laboratory Exercise

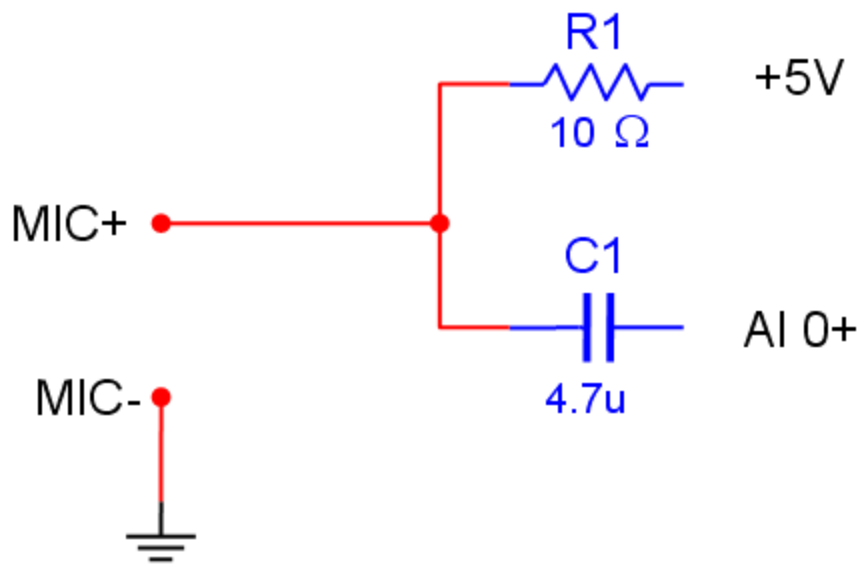
During this exercise, the experimenter will acquire a sound signal from an electret microphone element. This sound signal will then be run through an optional band-pass filter and played back using speakers.

When completed, the completed sound recorder front panel will resemble the following:



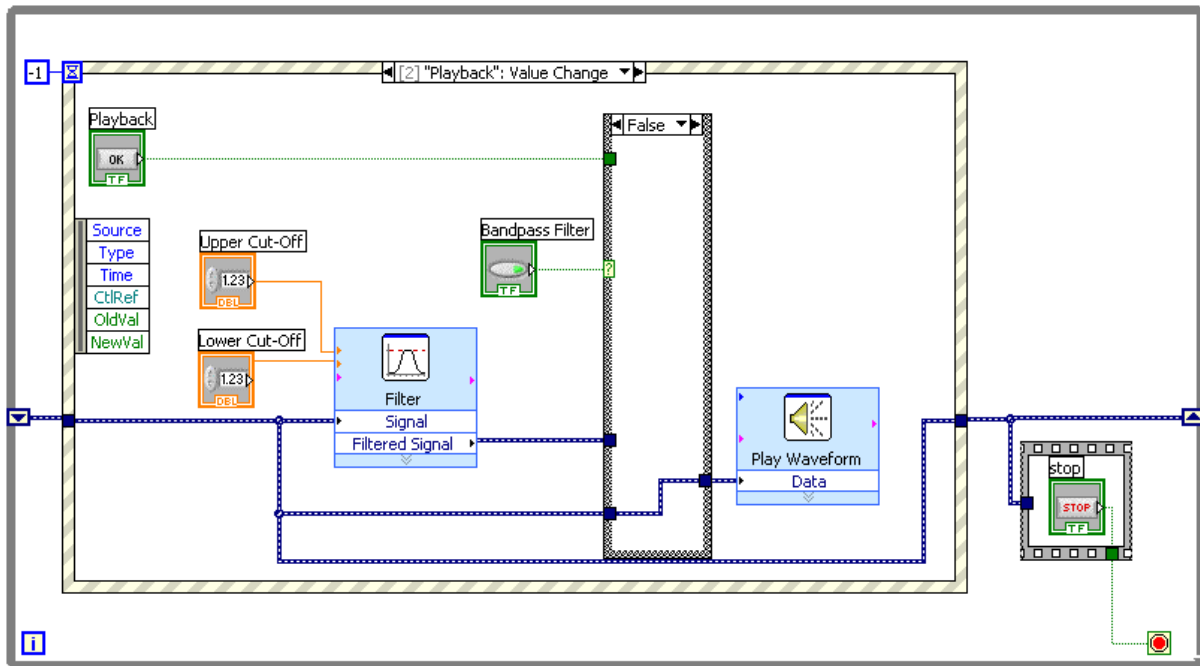
Completed Sound Recorder Front Panel in LabVIEW

1) Connect the following circuit to the Low Cost USB DAQ as shown. The microphone element can be purchased cheaply at Radio Shack, etc. Note that the +5V power supply can be obtained directly from the National Instruments USB 6008 or 6009 devices.



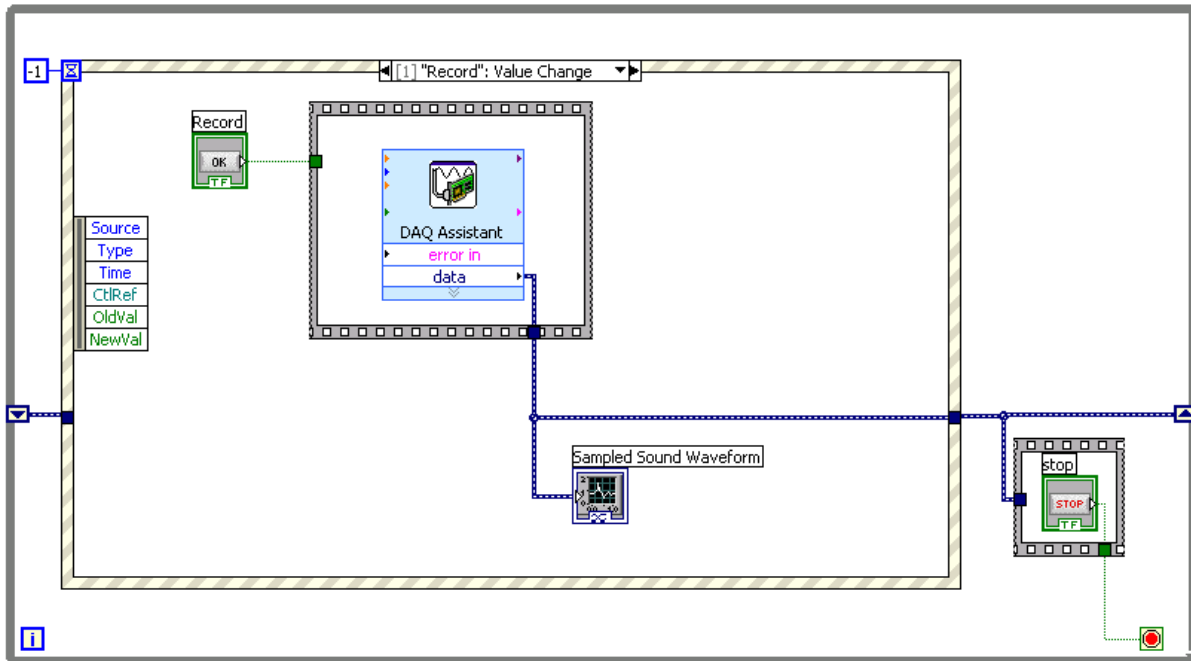
Electret Microphone Circuit

2) Using an event structure in LabVIEW, replicate the following block diagram for the “playback” event. Note that the “Bandpass Filter” Boolean control allows the user to play back the filtered or original signal.



Sound Recorder Block Diagram Showing Playback Event

3) Using the DAQ Assistant Express VI, complete the block diagram for the “record” event as indicated below:



Sound Recorder Block Diagram Showing Record Event

4) Experiment with the sound recorder VI by recording a simple voice message. Attempt to play back both the original and filtered signals. Modify the filter cut-off frequencies and see how narrow you can make the passband before the played back signal is difficult to decipher.

## Post-Lab Questions

- 1) What sample rate did you use when recording your sound signal? Explain why you chose this rate and what issues could occur with too low or high of a sample rate.
- 2) Could you have used any other filter types to clarify the sound signal? Would a low-pass, high-pass, or other filter have accomplished the same objective?



3) How can you tell if high frequency noise is present in your sound signal without playing it back? Before filtering the signal, how could you have determined what frequencies the signal contained?

## Microphone FFT Lab

# Microphone FFT Using National Instruments Low Cost Data Acquisition

### Introduction

Whenever a sound is made, a pressure wave travels through a medium (such as air) and vibrates our eardrums. This same principle can be used to convert sound information into an electrical form so that the experimenters can visualize, interpret, and analyze the sound information.

In addition to visualizing the amplitude of a sound wave (electrically) over time, we can also look at the frequency content of the sound signal. Simply put, we can use the Fast Fourier Transform (FFT) algorithm to look at how much of each frequency the sound signal contains. More information on the FFT will be provided in the theory section.

During this exercise, the experimenters will use a microphone element to convert a sound wave into an electrical signal. This signal will be then digitized using a Low Cost USB DAQ device. Finally, the Signal Express application will be used to quickly visualize the time domain sound signal as well as compute its Fast Fourier Transform for viewing in the frequency domain.

### Pre-Lab Assignment

- 1) Find a microphone element datasheet by searching the internet for “electret condenser microphone element.” Most detailed datasheets should show the frequency response curve of the element. This curve shows how much of each sound frequency makes it through to the electrical signal produced. What does this curve look like for the element you found?
- 2) What frequency response would be ideal for a microphone element to have? Would a flat curve be advantageous? What about a curve that rolls off

at 5 Hz? Hint: first determine which frequencies are audible to the human ear.

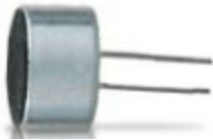
3) Write a short summary about how the electret microphone works. You should be able to find a variety of sources online; Wikipedia is a good starting point.

4) Become familiar with the National Instruments USB 6008 and 6009 data acquisition devices. These datasheets are available at [www.ni.com](http://www.ni.com).

## Theory

### Electret Microphone Elements

One way to convert sound pressure waves into an electrical signal is using an electret microphone element. A picture of such an element is shown below:



Electret  
Microphone  
Element

Inside the electret microphone element, a dielectric material is made to hold a permanent charge. When the element vibrates, the internal capacitance changes and an electrical signal is produced. A variety of additional components inside the microphone element act as a small output amplifier.

## **The Fast Fourier Transform (FFT)**

It is very common in science and engineering to view a signal's amplitude vs. time. For example, imagine that a doctor is watching a patient's heartbeat on an electrical device. He might see peaks in the heartbeat signal every 1 second if the patient's heart beats 60 times a minute.

If the doctor wishes to calculate the patient's heart rate (assuming it is perfectly steady), he can try to measure the time between successive peaks on the screen (1 second in this case) and calculate the heart rate from that information. However, there is an easier way!

Any signal (electrical or otherwise) can be viewed as a number of sine waves at different frequencies with various amplitudes and phase shifts. Simply put, a graph can be made that shows amplitude vs frequency instead of amplitude vs time. In the doctor's case above, it would be very convenient for him to have a graph of amplitude vs heart rate frequency. If the patient's heart rate is approximately 1 Hz as noted above, then the amplitude vs frequency plot should show a peak somewhere near 1 Hz as well. Now, the doctor can simply glance at the graph to see the heart beat frequency.

In order to convert a time domain signal such as heart rate amplitude vs time into the frequency domain to produce a plot such as amplitude vs frequency, the Fourier Transform can be used. Several variations of this transform exist, including the Fast Fourier Transform (FFT) algorithm that is typically used by computers. For the purposes of this exercise, the low level mathematical details of the transform will not be needed. The experimenter does, however, need to remember the basic concept:

Remember, any signal can be thought of as being composed of sine waves, where each frequency of sine wave will have a given amplitude and phase shift.

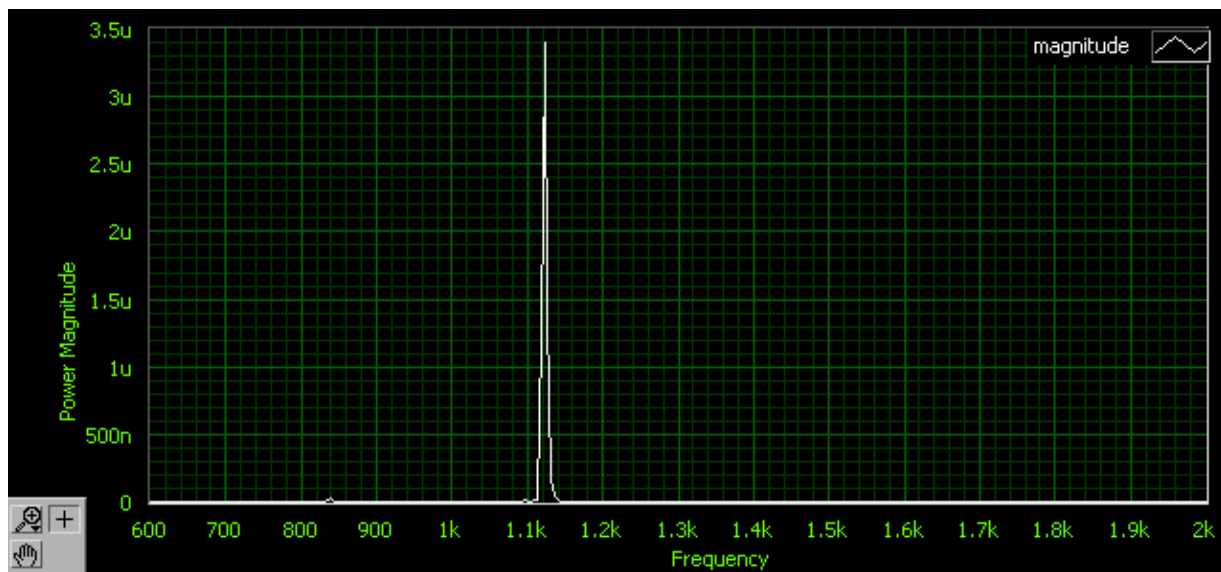
## **Hardware and Software Required**

1. 10 Ohm resistor

2. 4.7 uF capacitor
3. Electret microphone element
4. National Instruments Low Cost USB DAQ
5. Signal Express software

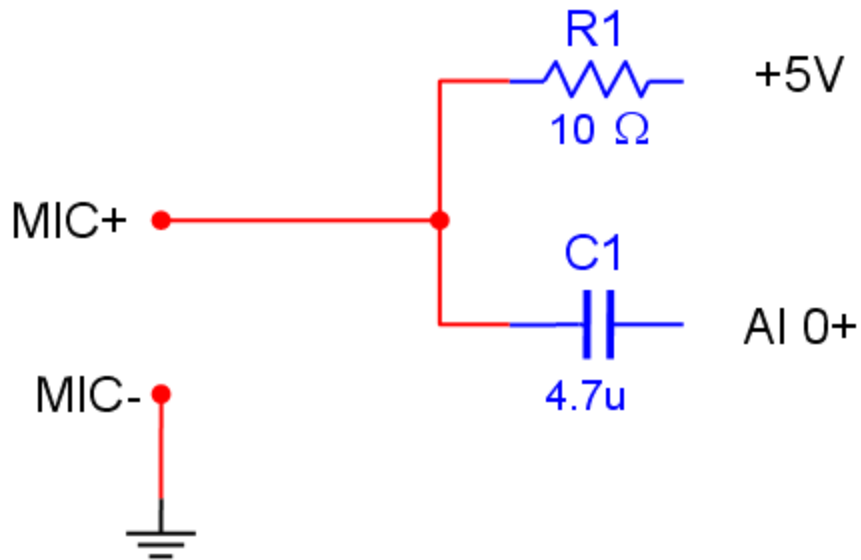
## Laboratory Exercise

During this exercise, the experimenter will acquire a sound signal from an electret microphone element. This sound signal will then be converted into the frequency domain using the Fast Fourier Transform to produce a chart similar to the following:



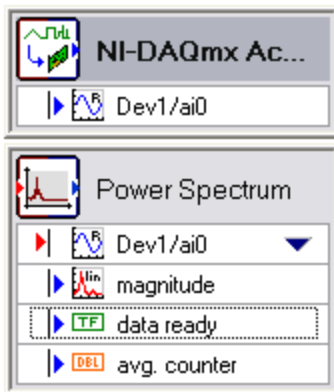
Frequency Domain Representation of Microphone Signal

1) Connect the following circuit to the Low Cost USB DAQ as shown. The microphone element can be purchased cheaply at Radio Shack, etc. Note that the +5V power supply can be obtained directly from the National Instruments USB 6008 or 6009 devices.



Electret Microphone Circuit

2) Program steps in National Instruments Signal Express software to match the sequence below. These steps will acquire a sound signal from the circuit constructed above and compute the frequency domain representation using the FFT.



Completed  
Signal Express  
Steps

3) Drag the acquired time domain sound signal as well as the frequency domain (FFT) signal into the data view window. Choose “run continuously” within Signal Express to loop the sequence.

4) Try generating various sounds by talking, whistling, etc. Make sure that you are close to the microphone element. Observe the FFT signal when you whistle different notes.

### **Post-Lab Questions**

1) Do research in a textbook or online to determine the frequency range that the human voice can produce. Did the FFT of your voice / whistling fall within that range?

2) Imagine you tried to use the electret microphone element outside on a windy day. What might happen if you tried to record your voice? How does the frequency response of the microphone play a factor here?

3) How can you tell if high frequency noise is present in your sound signal without playing it back? Hint: think about the concepts discussed in the theory section above.

4) What could be added to the Signal Express sequence above in order to attenuate any noise in your sound signal? What frequency ranges must remain intact (assuming you are attempting to record a human voice)? What frequency ranges do you not have to be concerned about at all?